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A Comparison of DEA, DFA and SFA Methods using Data from Caspian Cattle Feedlot Farms

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Abstract: Data Envelopment Analysis (DEA) is a non parametric data analytic technique that is extensively used by various research communities. In this study, we investigate the relative operating efficiencies of a set of cattle feedlot farm in Iran. The study analyses the technical efficiency the Caspian cattle feedlot farms over the periods 2007-2008. Stochastic Frontier Approach (SFA) and Data Frontier Analysis (DFA) indicate a generally low level of technical efficiency with significant inefficiency differences among farms. Specially, the econometric results suggests that stochastic frontier model generates lower technical efficiency estimates than parametric and nonparametric deterministic models, while parametric deterministic frontier model yields lower estimates than the nonparametric model DEA.

Key words: Data envelopment analysis, data frontier analysis, stochastic frontier approach, cattle feedlot, efficiency

INTRODUCTION

For all agricultural sectors, achieving a high level of efficiency is an important task. Cattle raising has been proven as a main resource to supply meat in Iranian agricultural industry. The meat consumption in Iran is evaluated to be about 12 kg per person and approximately, 65244 tons were imported in 2007. One of the most important ways to become free of need of meat in developing countries is the development of an efficient farm and the improvement of an inefficient farm (IRICA, 2009).

In the last two decades, several agricultural policies in Iran have attempted to improve the performance of this industry, but none of these policies were scientific.

Due to the arguments presented above, it is important to assess the efficiency of Iranian Caspian cattle feedlot farms.

As we know, the technical efficiency of a farm measures its success in producing maximum outputs from a given set of input. As is well established in the literature, productivity growth can be decomposed into Technological Change (TC) and Technical Efficiency (TE). This decomposition makes it possible to study the sources of productivity growth from different points of view. Specifically, TE can be interpreted as a relative measure of managerial ability for a given technology, while TC evaluates the effect in productivity from the adoption of new production practices. In other words, gains in TE are derived from improvements in decision-making, which in turn are related to a host of variables including knowledge, experience and education. By contrast, TC relates to investments in research and technology.

The purpose of this study is to analysis the technical efficiency in Caspian cattle feedlot farms in Iran by using parametric and nonparametric techniques such as DEA, Data Frontier Analysis (DFA) and Stochastic Frontier Analysis (SFA).

Data envelopment analysis (DEA) is a nonparametric technique for measuring and evaluating the relative efficiencies of decision making units (DMUs). Since the pioneering research of Charnes *et al*. (1979), DEA has demonstrated to be an effective technique for measuring the relative efficiency of a set of DMUs which utilize the same inputs to produce the same outputs.

The aims of this study is thus to evaluate the technical efficiency in Caspian cattle feedlot farms In Iran. A comparison of DEA, DFA and SFA results is put forwarded.

Data Envelopment Analysis (DEA), introduced by Charnes *et al*. (1979), provides a nonparametric

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methodology for evaluation the relative efficiency of each of a set of comparable decision making units (DMUs), relative to one another. The definition of a DMU is generic and DMUs can be in business firms and others.

In measuring TE, different methodologies and strategies have been proposed and considerable controversy has surrounded the choice and merits of a specific methodology and the impact of such choice on the ensuing analysis. Wadud and White (2000) indicate that in most empirical studies the selection of the methodology used to measure of TE is arbitrary and mainly based on the objective of the study, the data variable and the personal preference of the researcher.

In Cook and Green (2005), the DEA technique was used to evaluate the operational efficiency of a set of electric power plants and of the individual power units that make up those plants.

Lin *et al*. (2009) have used the DEA technique to evaluate the operating efficiency of each branches of the case bank in 2006 in an attempt to have more objective and impartial measuring indices for appraising the operating performances of branches and proposed the suggestions for each management DMUs while providing for head quarter management unit to allocate internal objectives to branches, branches operating advantages and disadvantages can be known.

Erbetta and Rappuoli (2008) applied the DEA technique to determine the optimal scale in the Italian gas distribution industry. Stochastic Frontier Analysis (SFA) and Data Envelope Analysis (DEA) are introduced to measure and compare the technical efficiency scores for 79 forest and paper companies by Lee (2005). They suggested that using only one of these methods to improve efficiency may cause incorrect measurement of increase output or reduce input since each of these approaches has some inherent limitations. Before any correctional improvements are taken, the stability of the technical efficiency estimates from a parametric (or nonparametric) method should be evaluated by comparing them against those found using the nonparametric (or parametric) method.

This type of study can be found in the sectors of public education by Chakraborty *et al*. (2001), banks by Kohers *et al*. (2000) and public schools by Ruggiero and Vitaliano (1999) and Hjalmarsson *et al*. (1996).

AN INTRODUCTION TO DEA, DFA AND SFA

DEA efficiency analysis: To describe the DEA efficiency measurement, let there are n DUMs and the performance of each DMU is characterized by a production process of m inputs (x_{ij} : i = 1,...,m) to yields s outputs (y_{ri} : r = 1,...,s). The ratio DEA model also known as the CCR model, measures the efficiency of DMU_o as the maximum of the ratio of its weighted outputs to its weighted inputs as:

$$\theta_o = \sum_{r=1}^{s} u_r y_{ro} \Big/ \sum_{i=1}^{m} v_i x_{io}$$

where, the maximum is sought subject to the conditions that this ratio does not exceed one for any DMU_j and all the input and output weights are positive. To estimate the DEA efficiency of DMU_o, we solve the following DEA model (Charnes *et al*., 1979):

$$\begin{aligned} &\text{Max} \quad \theta_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \\ &\text{s.t} \quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1, \qquad j = 1,...,n,\ u_r, v_i \ge \varepsilon, \quad \text{for all r, i} \end{aligned} \tag{1}$$

where, ε>0 is a non-archimedean construct. This linear fractional programming problem can be reduced to a non-ratio format in the usual manner of Charnes and Cooper (1962). Specifically, make the transformation

$$[\sum_{i=1}^{m} v_i x_{io}]^{-1} = 1$$

and let

$$\bar{v} = tv \text{ and let and } \bar{u} = tu$$

Then Eq. 1 can be expressed in the form:

$$\begin{aligned} &\text{Max} \quad \theta_o = \sum_{r=1}^{s} \bar{u}_r y_{ro} \\ &\text{s.t} \quad \sum_{i=1}^{m} \bar{v}_i x_{io} = 1, \\ &\qquad \sum_{r=1}^{s} \bar{u}_r y_{rj} - \sum_{i=1}^{m} \bar{v}_i x_{ij} \le 0, \quad j = 1,...,n,\ \bar{u}_r, \bar{v}_i \ge \bar{\varepsilon}, \quad \text{for all r, i} \end{aligned} \tag{2}$$

This model is a Constant Returns to Scale (CRS) program and assumes that all input/output data are known exactly and all produced outputs are perfect and complete. The efficiency ratio θ_o ranges between zero and one, with DMU_o being considered relatively efficient if it receives a score of one. From a managerial perspective, this model delivers assessments and targets with an output maximization orientation.

SFA (stochastic frontier approach): The stochastic frontier production function was independently proposed by Aigner *et al.* (1977) and Meeusen and Van den Broeck (1977). The original specification involves a production function specified for cross-sectional data which has an error term which is comprised of two components, one to account for random effects and another to account for technical inefficiency. This model can be expressed in the following form:

$$Y_i = X_i\beta + (V_i - U_i), \quad i = 1, \cdots, n$$

where, Y_i is the production (or the logarithm of the production) of the i-th firm, X_i is a k×1 vector of (transformations of the) input quantities of t he i-th firm, β is an vector of unknown parameters, ε_i s are random errors with $N(0, \sigma^2 V)$, which are associated with random factors such as measurement errors in production and independent of the U_i, which are non-negative random variables which are assumed to account for technical inefficiency in production and are often assumed to be symmetric independently distributed as $N(0, \sigma^2, U)$ random variables and independent of U_i. This original specification has been used in a vast number of empirical applications over the past two decades. A number of comprehensive reviews of this literature are available, such as Forsund *et al.* (1980), Schmidt (1986), Bauer (1990) and Greene (1993).

DFA (deterministic frontier approach): For DFA analysis, we estimated Cobb-Douglas production function by the Ordinary Least Square (OLS) method. In this method, the differences between actual production and Frontier Production Attributed to management factors. The Deterministic Frontier Production function was expressed in the following forms:

$$\ln y_j = \sum_{i=1}^{m} \beta_i \ln X_{ij} - \varepsilon_j$$

where, y_i is output of farm j; j; X_{ij} is input i that farm j be used. β_i is the OLS estimated coefficient of input i (the elasticity of input i). ε_j is representation of technical efficiency of farm j.

$$\sum_{i=1}^{m} \overline{\beta}_i \ln X_{ij} = \ln \overline{y}_j \geq \ln y_j$$

In $\overline{y}_j$ is estimated production of farm *j* that is greater than or equal to its actual production ($\ln y_j$). Only in farms that having 100% technical efficiency, In $\overline{y}_j$ = In y_i. So we solve the following:

$$\text{Min} \quad \sum_{j=0}^{m} \varepsilon_j$$

$$\text{s.t.} \quad \ln \overline{y}_j \geq \ln y_j$$

Then technical efficiency is determined as:

$$TE_j = \frac{y_j}{\overline{y}_j}, \quad j = 1, \cdots, n$$

METHODOLOGY AND DATA DESCRIPTION

This study utilizes DEA as it is an approach that can easily model slacks, even though there exists some literature on the separate estimation of technical and allocative inefficiencies using stochastic frontiers Kumbhakar and Lovell (2000), Kumbhakar and Tsionas (2004). DEA studies, however, do not explicitly account for slack variables in the relative efficiency analysis. As Fried *et al.* (1993) point out," The solution to DEA problem yields the Farrell (1957) radial measure of technical efficiency plus additional non-radial input slacks and output surpluses. In typical DEA studies, slacks and surpluses are neglected at worst and relegated to the background at best. Such input and output slacks are essentially associated with the violation of neoclassical assumption. If we take the standard input-oriented DEA approach, for example, input slacks would be associated with the assumption of strong or free disposability of inputs. Hence, units with extensive usage of some inputs would be deemed to be efficient according to standard Banker *et al.* (1984). If slacks were incorporated into the relative efficiency analysis, however, such units could actually be found to be inefficient.

For the reasons outlined above, therefore, we feel it is appropriate to use the Slack-Based Measure (SBM) of Tone (2001). This SBM approach specifically incorporates slacks in the objective function. To describe the SBM model of Tone, let there are n DMUs and the performance of each DMU is characterized by a production process of m inputs(x_{ij} : i = 1,...,m) to yields s outputs (x_{ij} : i = 1,...,s):

$$\text{Min} \quad e_o = t - \frac{1}{m}\sum_{i=1}^{m}\frac{s_i^-}{x_{io}}$$

s.t.

$$1 = t + \frac{1}{s}\sum_{r=1}^{s}\frac{s_r^+}{y_{ro}}$$

$$x_{io} = \sum_{j=1}^{n}\lambda_j x_{ij} + s_i^-$$

$$y_{ro} = \sum_{j=1}^{n}\lambda_j y_{rj} + s_r^+$$

$$\lambda_j, s_i^-, s_r^+ \geq 0$$

The optimal solution is when $e_0 = 1$ and hence a DMU will have zero input and output slacks and be fully efficient on the frontier. We also have used Stochastic Frontier Analysis (SFA) and frontier analysis to evaluate the cattle feedlot farms. The sample consisted of around 70 Iranian Caspian cattle feedlot farms. The data for this analysis are derived from operations during 2007 and 2008.

The raw data are reported in Table 1. We use six variables from the data set as inputs and outputs. Inputs include number of calve per farm (x_1), number of labors/ days/hours (x_2), total metabolizable energy intake (Mcal) (x_3), total crude protein intake (kg) (x_4) and total cost of hygiene- treatment of calve (Rials) (x_5).

The unique output is total live weigh gain of calve per farm (kg) (y).

Details of inputs and outputs are defined below:

- Calve per farm: Number of calve per farm
- Labors: Number of labors
- Metabolizable energy intake
- Crude protein intake
- Cost of hygiene- treatment of calve
- Live weight gain of calve per farm

EMPIRICAL RESULTS

Table 2 presents the estimation results of the cost and technical frontiers, as the table indicates, 11 farms are efficient in DEA. However, we note that except for farm 3, all of the other farms are inefficient in DEA and DFA approaches.

We also have calculated the correlation between the mean of technical efficiencies calculated in different methods. The results are listed in Table 3, as we can see there is a significant correlation in different methods. The maximum correlation is DFA and SFA, while the minimum one is in DEA and DFA. It is to be noted that DEA is a nonparametric approach, while DFA is a parametric approach. Efficiency intervals in three methods DFA, DEA and SFA are, respectively (0.15 , 1), (0.2 , 1) and (0.183 , 1). As we can see, farm 3 is the top-ranked farm and farm 13 is the low-ranked in three methods.

Table 4 presents Descriptive Statistics of technical efficiency, means of technical efficiency in DFA(0. 6910) is the least and significantly different with SFA(0. 6910) and DEA(0. 7221) Methods($p<0.01$).

Table 1: Variables and raw data get as inputs(x1…x5) and output(y)

No.	y	x_1	x_2	x_3	x_4	x_5	No.	y	x_1	x_2	x_3	x_4	x_5
1	8820	40	240	194950.10	13631.900	664000	36	1000	10	144	29565.56	1845.835	275000
2	2478	14	94	30442.04	1738.086	200000	37	1504	14	89	24047.38	1135.571	158667
3	1705	11	123	14435.70	803.8679	1970000	38	2093	15	131	34973.82	2322.347	1166667
4	5776	32	107	188344.50	9824.743	207320	39	2304	24	73	35184.23	2159.511	323333
5	3520	22	135	48434.73	2377.013	720000	40	1178	15	151	29202.7	1576.433	503333
6	660	15	42	15170.10	742.0112	37333	41	274	8	57	10320.3	585.0152	253333
7	4208	32	126	133026.70	7613.183	1302000	42	4250	50	150	101850.8	5858.997	1500000
8	1104	23	60	109637.50	5423.258	668000	43	3496	38	141	88012.38	5362.142	2350000
9	870	10	42	18472.61	826.6245	186667	44	2697	21	158	16668.96	811.1912	700000
10	5160	40	360	154528.40	8294.19	1800000	45	480	8	120	11456.25	695.835	480000
11	4550	65	139	79314.00048	4999.463	1390000	46	1620	18	120	63160.09	3802.571	1000000
12	1211	17	53	25856.28	1752.804	100000	47	486	17	108	15005.7	977.138	408000
13	557	32	98	31199.44	1571.243	600000	48	2131	36	112	90986.26	5561.208	1120000
14	3212	22	105	77906.93	3453.03	1400000	49	677	8	113	26100	1350.24	500000
15	7849	54	210	327116.50	15771.19	1750000	50	1056	12	127	28560.33	1793.437	1126667
16	4112	38	326	68289.74	3869.825	1738667	51	1476	9	198	30907.48	1316.371	880000
17	5962	36	204	161843.40	7299.915	1700000	52	384	10	96	10842.62	615.8054	320000
18	8084	69	300	217788.50	10497.01	877795	53	689	17	90	30189.2	1681.061	450000
19	3405	30	148	89896.57	4337.419	888000	54	14400	120	636	479779.6	32453.25	3533333
20	3421	24	210	125338.30	5617.393	700000	55	2752	43	120	26499.93	1232.895	2000000
21	4477	32	116	50264.49	2329.411	386667	56	982	13	80	20190.46	1187.3	800000
22	5148	42	150	85976.27	4037.147	750000	57	7800	100	450	212177.3	12026.09	2500000
23	1162	14	72	27732.64	1328.007	143000	58	795	20	75	16941.6	962.196	375000
24	4356	39	159	56238.11	3433.674	477000	59	677	6	75	16185.31	816.9876	400000
25	6156	27	190	104028.30	4976.108	1055577	60	488	6	94	18232.88	1035.939	500000
26	1311	19	67	51856.31	2740.486	443333	61	3386	95	132	107223.4	6903.833	2200000
27	1424	24	97	33058.90	2013.957	323333	62	879	15	47	23208.46	1364.546	310000
28	1440	32	180	62598.14	3839.862	480000	63	800	8	120	7583.81	442.1621	400000
29	1321	12	144	28567.99	1275.623	320000	64	2520	20	210	55141.55	3039.429	1050000
30	2518	19	124	30443.99	1572.734	440000	65	647	11	90	22413.09	1269.955	400000
31	6664	40	150	103023.90	6547.7410	750000	66	1649	23	132	68720.47	3386.676	1100000
32	942	10	75	8467.70	415.4802	100000	67	700	8	125	18710.92	1100.968	666667
33	4250	17	240	81219.50	5538.9040	1600000	68	3931	28	234	114659.2	6216.4	2340000
34	1969	18	81	42487.78	2801.2580	360000	69	3135	23	160	45998.73	2510.93	1600000
35	1488	14	131	35363.79	1669.2420	291667	70	1760	50	79	40645.77	2342.184	1053333

Table 2: Technical efficiency estimated by DFA, SFA and DEA methods

Firm	DFA	SFA	DEA	Firm	DFA	SFA	DEA
1	0.73	0.86	1	36	0.39	0.49	0.498
2	0.94	0.93	1	37	0.58	0.75	0.788
3	1.00	0.93	1	38	0.75	0.86	0.762
4	0.63	0.85	1	39	0.79	0.89	0.795
5	0.77	0.89	0.936	40	0.37	0.47	0.466
6	0.40	0.53	1	41	0.27	0.35	0.236
7	0.58	0.78	0.732	42	0.51	0.67	0.654
8	0.24	0.37	0.343	43	0.54	0.71	0.577
9	0.61	0.81	0.586	44	0.89	0.90	1
10	0.37	0.49	0.565	45	0.35	0.42	0.393
11	0.59	0.73	0.784	46	0.41	0.55	0.417
12	0.62	0.77	0.831	47	0.24	0.30	0.245
13	0.15	0.20	0.183	48	0.36	0.49	0.418
14	0.63	0.85	0.802	49	0.32	0.44	0.401
15	0.43	0.63	0.775	50	0.45	0.57	0.476
16	0.46	0.56	0.655	51	0.45	0.60	0.808
17	0.52	0.73	0.802	52	0.27	0.34	0.277
18	0.39	0.53	0.717	53	0.26	0.35	0.261
19	0.48	0.66	0.625	54	0.35	0.45	0.593
20	0.37	0.52	0.645	55	0.65	0.79	0.937
21	0.82	0.91	1	56	0.55	0.70	0.501
22	0.62	0.80	0.852	57	0.31	0.40	0.483
23	0.47	0.63	0.631	58	0.39	0.49	0.424
24	0.70	0.82	0.846	59	0.53	0.70	0.583
25	0.76	0.89	1	60	0.35	0.46	0.398
26	0.41	0.58	0.447	61	0.35	0.45	0.563
27	0.44	0.55	0.459	62	0.52	0.69	0.468
28	0.23	0.30	0.275	63	0.67	0.75	0.741
29	0.41	0.54	0.645	64	0.48	0.61	0.645
30	0.74	0.86	0.866	65	0.33	0.43	0.340
31	0.88	0.92	1	66	0.31	0.44	0.368
32	0.72	0.83	1	67	0.40	0.50	0.477
33	0.78	0.88	1	68	0.46	0.62	0.605
34	0.69	0.84	0.653	69	0.70	0.84	0.801
35	0.42	0.56	0.602	70	0.42	0.54	0.551

Table 3: Pearson correlations

	DFA	SFA	DEA
DFA	1.0	0.965**	0.858**
SFA	0.965**	1.0	0.874**
DEA	0.858**	0.874**	1.0

**Correlation is significant at the 0.01 level (2-tailed)

Table 4: Descriptive statistics of technical efficiency

Method	Mean	SD	SE	Minimum	Maximum
DFA	0.5986a*	0.19497	0. 02538	0.18	1.00
SFA	0.6910b	0.16827	0.02280	0.23	0.93
DEA	0.7221b	0.22800	0.02805	0.23	1.00

*Difference is significant ($p<0.01$), (cal $F = 6.166$), ($N = 59$)

Efficiency scores in this study were estimated using the computer programs, DEAP Version 2.1 (Coelli, 1996), FRONTIER Version 4.1 and SPSS Statistics 17.0.

CONCLUSIONS

This study uses the DEA, DFA and SFA to evaluate the operating efficiency cattle feedlot farms. The paper has taken 70 farms in Iran in 2007-2008 as the research subject and has used DEA, DFA and SFA to evaluate the operating performances of these farms. The results indicated that 11 farms are efficient in DEA technique. However, in DFA and SFA, the number of efficient farms are 1 and 0, respectively. Moreover, the average technical efficiency of farms in DFA, SFA and DEA were respectively, 0.5986, 0.6910 and 0.7221.

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